SMALL SATELLITE PORTFOLIO
AIR FORCE RESEARCH LABORATORY

A New Mission Assurance Concept for Small Satellites and Derived Best Practices

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SmallSat Mission Assurance Realities

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Constraint Driven

Mission scope fits into capabilities and complexity available given technical, programmatic and oversight needs

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Fit within the "box" given to you

CONSTRAINT DRIVEN

Mission scope fits into capabilities and complexity available given technical, programmatic and oversight needs

REQUIREMENTS DRIVEN

Mission scope is static and resources applied to achieve that mission

Build your own box

SmallSat Mission Assurance Realities

1. Constraint-driven missions are the most common
2. Class D mission assurance practices are significantly modified or ignored
3. Class D overhead can dilute the full potential contribution of small satellites

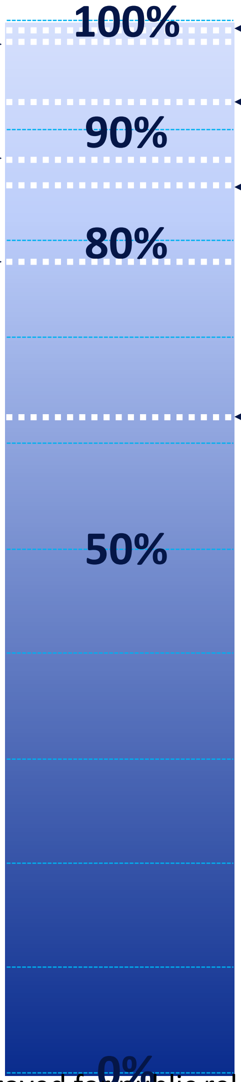
FASTER INNOVATION | LOW-COST DEVELOPMENT | EDUCATIONAL OPPORTUNITIES

Percentage of Spacecraft Success

98.5% - Large S/C survive ≥ 6 months

87% - Pico/NanoSats that communicate, ~2017

78% - CubeSats that communicate, 2000-2016



99% - US Human Spaceflight 1959-2017 (loss of life)

94% - "Big space" CubeSats / ALL LVs '07-'17

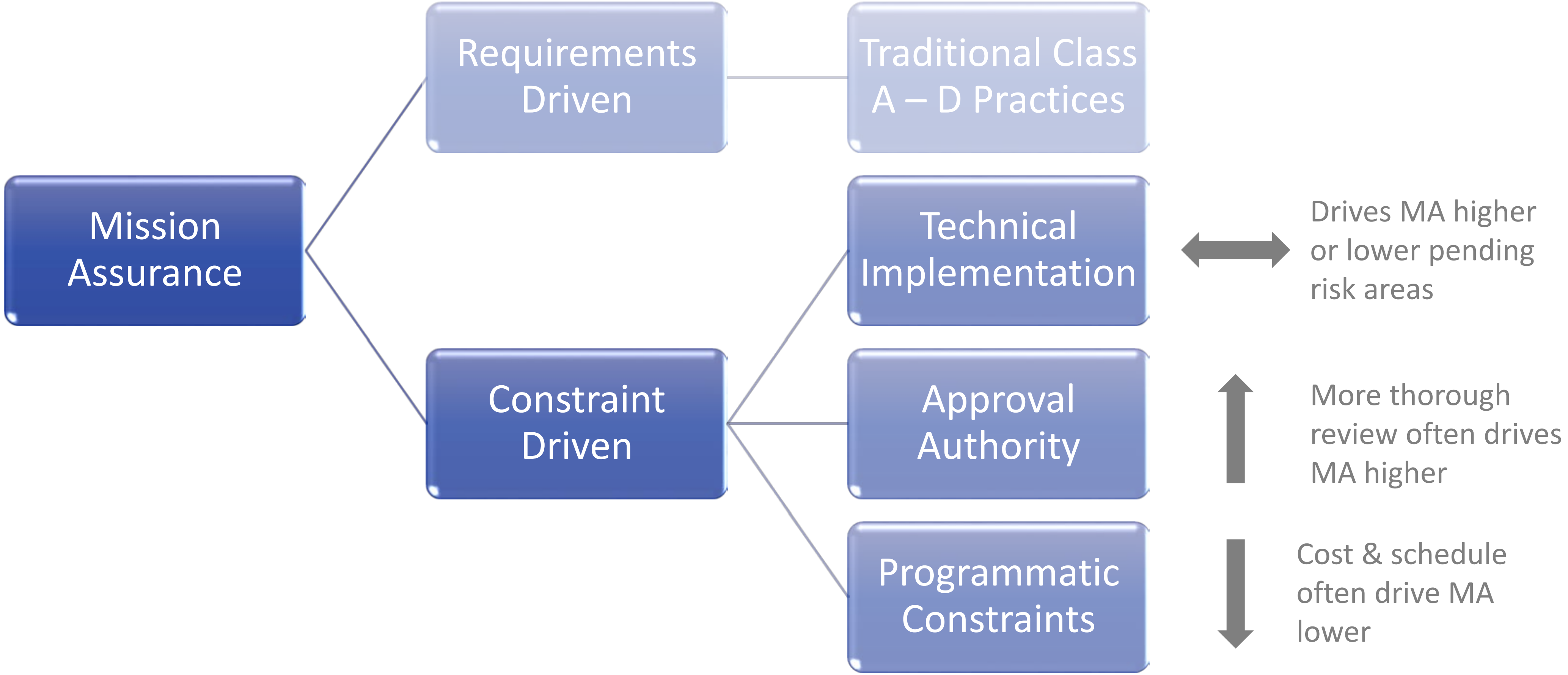
85% - CubeSat Industry not DOA

63% - Hobbyist CubeSats not DOA

How can I push the boundary of faster innovation while still achieving an acceptable Return-on-Investment?

What are the minimum practices I should use to meet constraint-driven goals?

Elements of constraint driven MA



At inception, the stakeholders and designers should have an honest conversation about whether the mission is requirements or constraint driven

Technical implementation taxonomy

Demonstrated Level of Capability	Implication
Do No Harm	DOA is ok (education and/or fully constrained and not requirement driven)

All missions are designed for full mission success; the amount of mission assurance can provide a level of confidence in mission success

Technical implementation taxonomy

Demonstrated Level of Capability	Example Technical Activities	Example Approval Authority (AA)/Oversight	Programmatic
Do No Harm	Vibration testing, bake out, inhibit design review/test, range safety measures demonstrated, no RF transmission within 45 minutes of deployment/no attitude maneuvers within 15 minutes, 25 year deorbit.	AA: Program Reviews: informal peer, launch readiness.	Fully constrained, schedule + cost allow launch requirement verification only
Survival	(All of the above), possibly designing power/comm for tumble, long range communications testing with ground station has been completed(1), complete charge/discharge cycle testing completed(2), TVAC.	AA: Program Reviews: informal peer, may have stakeholder.	Mostly constrained, schedule + cost do not allow significant confirmation of capability beyond survival
Minimum Functionality	(All of the above), full command execution test(3), startup/POR DitL testing(4), Sun-point test(5), other mission specific tests demonstrating survival functionality, mission specific FTA & Self-EMC test, thermal analysis.	AA: Program +1 level Stakeholder input Reviews: informal-SCR, PDR, CDR, TRR, LRR	Mostly constrained, schedule + cost allow confirmation of capability to achieve minimum success
Nominal (**constraints**)	(All of the above), environmental characterization and flow down into requirements (i.e. radiation), full functional and limited performance testing, more detailed FTA & FMEA (flight, ground, GSE), SPF analysis/redundancy, requirement development to at least L2 and V&V.	AA: Program +2 levels Stakeholder input/vote Reviews: formal-SCR, PDR, CDR, TRR, LRR.	Less constrained and more requirement driven, schedule + cost allow confirmation of capability to achieve full success
Nominal (**requirements**)	(All of the above), full functional and performance testing, Worst Case Analyses & design. NPR 8705.4, TOR-2011(8591)-21	AA: Director Stakeholder vote/driven	Fully requirement driven, schedule + cost allow confirmation of capability to achieve full success

Best practices: Programmatic

Well-defined mission success criteria AND constraints

- No hidden or underlying expectations
- Bounded by capabilities of SmallSat systems
- Constraint-driven: as the true capability is discovered, scope may reduce

Prioritized list of success criteria and constraints

- Have clarity on how important non-technical goals are (ex. teaming opportunities, education, schedule)
- Have a discussion on when/why a constraint will drive mission scope

Firm agreement between stakeholders and designers

- Scope creep/modifications not unique to small satellites, but can definitely dilute some of the advantages small satellites have with respect to cost and schedule

Best practices: Design

Design for full power resets

- Often the best and simplest way to handle LEO radiation
- Soft reset/POR is not good enough
- Watchdogs used on flight computer

Design for tumble

- Every SmallSat tumbles: kick-off, safe mode, etc.
- Comm link budget should close in most attitudes
- Power generation/energy balance should be positive in an understood set of tumble states

Create safe mode and re-programmability

- Safe mode should be power/energy positive in a tumble
- Simple and well vetted (i.e. lots of DitL spent here)
- Software that is re-programmable has saved many missions

Best practices: Testing

TEST, TEST, TEST!

1. Long Range Comm
2. Complete charge-discharge cycle

- Focus here is ensuring survival
- Incorporates best practice of “Design for tumble”

3. Command execution
4. Day-in-the-Life (DitL)
5. Sun pointing demonstration

- Focus here is demonstrating increase in vehicle capability
- DitL is even better as a week; can be elements of mission profile or with added complexity of long duration tests, performance characterization, etc
- Test #5: best ROI showing ADCS is functional & can perform the most important maneuver(s)

Conclusions

- New mission assurance profiles are needed that represent constraint driven mission sets
- Constraints ≥ science or technology objectives
- A clear scope and broad understanding of constraints drive implemented MA to have the greatest ROI
- Generally more constrained missions allow decisions in all areas to be made closer to the project implementers

Is this the right path? We want to engage with the community!

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